Issues concerning the teaching and learning of mathematics and numeracy in Australian schools

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Background

For over 30 years I have been involved in the teaching and learning of mathematics and numeracy in Australian schools. I taught mathematics in high schools (Years 8–12) for more than 20 years at different school settings ranging from rural and remote to inner city, high socio-economic status schools to schools of students mostly from poorer, lower socio-economic status parents. I worked as the senior curriculum officer for K–12 mathematics for the Department of Education in WA for over six years, during which time I visited many schools throughout the state and spoke with hundreds of classroom teachers of mathematics. During my two years as Curriculum Manager in the ACT I similarly worked with teachers from the entire territory and am currently assisting with implementation of a new mathematics syllabus in Queensland as part of my duties. My involvement in the national work in these areas has been the result of representing three jurisdictions at national forums and extensive work representing numerous associations of mathematics teachers, including the Australian Association of Mathematics Teachers (AAMT).

During this time I have gained a relatively comprehensive view of the issues and challenges facing the profession in relation to the improvement of student mathematics and numeracy outcomes. This paper attempts to share these views for the benefit of teachers, schools, school administrators and curriculum developers, in the hope that by articulating the issues some clarity will be achieved which will in turn shape efforts to address them.

Definitions

Numeracy as an outcome

Attempts to describe *numeracy* have generally focused on one of three approaches:

- what mathematics people know — a 'basic skills' approach;
- how well people apply mathematics to practical situations — a 'choosing and using' approach;
- how well people draw on mathematics when dealing with everyday situations in which mathematics is embedded — a 'mathematical literacy' approach.

Being numerate involves aspects of each of these; a person cannot be numerate unless they know some mathematics and a person cannot be numerate unless they can apply mathematics to practical situations or draw on mathematics when dealing with situations in which mathematics is embedded.

No single approach is adequate of itself. To

assume that someone is numerate because they know some mathematics is a nonsense; knowing some mathematics is essential but not sufficient. Tests that measure mathematics understandings and knowledge measure at best a person's potential to be numerate.

The Australian Association of Mathematics Teachers has the following as a working definition of numeracy:

> To be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life. (AAMT, 1997)

So being numerate involves a disposition or a confidence that must exist in order for people to choose to use the mathematics they know. Teachers play a vital role in developing numerate behaviours in children and young people through both the teaching of mathematics and the fostering of the disposition to use their mathematics.

Numeracy and mathematics

The range of definitions for numeracy and its connection with mathematics has resulted in a widespread misunderstanding about the nature of numeracy. If school leaders and teachers are unclear about how mathematics and numeracy connect they will be unlikely to be able to respond effectively to the demands that developing numerate children and young people place on them.

There are some aspects of mathematics that are not necessary for numeracy. Having a grasp of the field of algebra, for example, is not necessary in order to be numerate. Likewise, there are aspects of numerate behaviour that have little to do with mathematics. These aspects are about disposition and confidence, which emanate from an attitude of confidence that believes, "I can do this." Clearly there are some who have this attitude who do not know or understand much mathematics, but this does not stop them from using what mathematics they know even if it is not correct or appropriate in particular contexts. Application of incorrect mathematics may eventually reduce the level of confidence, which in turn can reduce the application of numerate behaviours.

Numeracy and literacy

"Literacy and numeracy" is a term frequently used to describe the foundational skills required by all students. In the minds of the general public, and indeed many educators, literacy and numeracy are inextricably linked.

This linking, combined with a widespread misunderstanding of numeracy when compared with the better understood area of literacy, has frequently resulted in funding of programs and strategies that claim to focus on both literacy and numeracy, but which in fact focus predominantly on literacy. This disproportionate imbalance in funding distribution has resulted in better teacher understandings of literacy and consequently better teaching and improved literacy outcomes for children and young people. Meanwhile, teaching and learning to improve numeracy outcomes has remained relatively unchanged in some quarters, as have student outcomes in numeracy.

The defining role of technology

Just as rapid change in technologies has demanded a redefinition of "literacy" and the acknowledgement of "multi-literacies", advancements in the capability and availability of computational and quantitative and graphical display technologies forces a reconsideration of many aspects of numeracy.

Much attention has been focussed on hand-held calculators and the misguided fear they generate in many parents (and some teachers) that their use will destroy computational facility in the next generation. There are however, many other devices with the potential to transform our current understanding of what it means to be a numerate adult. Hand-held global positioning (GPS) devices have altered the way that drivers and recreational fishers regard map reading. Cash registers that integrate electronic fund transfer and update a store inventory change what customers expect of a skilled sales assistant and indeed the way customers operate when making purchases.

Much time is currently devoted in many schools to teaching children to perform the tasks that a calculator (or other technological device) can do better. Conversely, little time may be devoted to developing the knowledge

and skills required to get best value from using a calculator efficiently and effectively, such as estimating expected results to judge the reasonableness of answers in given contexts.

The balance of the mathematics curriculum has altered to reflect these technological advancements. Whereas the curriculum once focussed on computation, it now focusses on higher order thinking around evaluating, justifying, judging the reasonableness of answers, making conjectures, and deciding the level of accuracy required in particular contexts.

The impact of national testing programs

Public recognition of the importance of (literacy and) numeracy is acknowledged, or perhaps, created, by the prominence given to the testing program in Aspects of Literacy and Numeracy at Years 3, 5 and 7 and to the reporting of individual and cohort results against nationally agreed benchmarks.

Systemic testing programs are an essential part of providing information about the health of education in Australia. We must however, realise the limitations of pen-and-paper tests for providing valid and reliable information about any one individual's knowledge, understandings and skills. What is desirable for all students in terms of numerate behaviours cannot be tested reliably on one day of the year during a two-hour pen-and-paper test.

The national testing program uses a "basic skills" definition of numeracy and tests by measuring their mathematical knowledge, the potential of students to be numerate. This limited definition has not contributed to enhanced public understanding of numeracy as a desirable outcome for Australian students. It can result in parental expectations that schools likewise adopt a "basic skills" approach to the teaching and learning of mathematics to improve the development of numerate behaviours in children, in order to match the restricted nature of the testing (i.e., a "teach to the test" approach).

Despite this definitional problem, the information made available to teachers and the system as a result of the testing should not be disregarded. It should help teachers to identify the needs of individual students and to target support to address them.

The nature of school mathematics

It is not the intention of this paper to paint a negative view of the teaching and learning of mathematics and numeracy in Australian schools. Indeed, there is widespread evidence of outstanding practice currently occurring in these areas of the curriculum in classrooms and schools across the country. The purpose of the paper is to identify issues that are challenges to the institutionalisation of this excellent practice. Broad statements made below about teachers and practices are generalisations made for the purpose of highlighting the issues. Suffice to say that the occurrence of practices identified below is sufficiently widespread for them to be identified as concerns.

Public perception

Public perceptions of "school mathematics" are based upon the collective experience of parents and the wider community who all went to school and studied something called mathematics for up to 12 years with a range of success. The fact that the nature or even the purpose of the subject might have altered with time is frequently disregarded. Many people expect that much the same subject matter will be taught in much the same manner as they experienced, however long ago.

Mathematics as a course of study is "values-laden". It carries with it a cachet of status derived from its traditional use as an indicator of academic potential and future success. This use is primarily based on the rigour associated with the logical thinking demands of the subject at its highest level and problem solving often associated with the subject. It has led some universities to demand certain levels of achievement in mathematics courses as prerequisites for entry, when in fact the mathematical knowledge contained in them may be neither needed nor relevant for further study.

This top-down recognition of high status has resulted in a pressure — either real or

perceived — to "maintain standards" in the subject as an indicator of tertiary readiness at the expense of "preparing students for life". An appropriate focus on developing the numeracy capabilities of all students needs to be given greater prominence over "preparing students for university" or even "preparing students for Year 11 and 12 courses that lead to university study", since by far the greater proportion of our students do not go to university.

Paradoxically, while the curriculum intent is often being maintained at elevated (even unrealistic) levels, some in the community are happy to accept indifferent performance (or even failure) from students. The most-frequently cited reason that many East Asian countries such as Korea, Hong Kong, Singapore, do so well on the TIMSS and PISA studies is the approaches taken in these countries to the learning and teaching of mathematics. Enormous parental pressure is placed on students to succeed through an ethos of, "Try harder; you can do it," as opposed to a "Don't worry about it; I was never any good at maths" ethos that exists in some parts of Australian culture. High expectations from all parents and carers as well as from all teachers are needed if all our students are to succeed.

I suggest also that a culture of low expectation may result from school administrative arrangements such as the streaming and labelling of students and courses (e.g. "foundational maths", "basics maths class", "less able maths course") leading often to self-fulfilling prophecies of failure or lack of success.

Curriculum content

Schools or teachers who accept that it is primarily their role to prepare their students for the next phase of learning often believe that this "preparation" is about teaching the content demanded at the next phase. This may result in a focus on correct answers that frequently denies opportunities for lateral thinking, higher order thinking skills, reflective learning, metacognition and a preparedness to take risks. This in turn can take the enjoyment out of learning mathematics for many students and can result in a lack of the confidence needed by students to apply their mathematics outside the classroom.

In many mathematics classrooms there is a disproportionate imbalance in the time spent doing written calculation as opposed to mental calculation. Frequently this written calculation focusses on mindless practicing of algorithms and procedures, which will not generally increase understanding or learning of mathematic concepts and can be viewed as "busy work". The SAUCER research from Edith Cowan University (1998) indicated that the majority of mathematics used by adults in life involves mental computation or the use of a computational tool. Hence it may be argued that a focus on written calculation is inappropriate.

Confronting the changes needed to redirect mathematics teaching and learning to serve the greater needs of numeracy will involve an examination of both subject matter content and pedagogical practices used in its delivery.

Teaching methods

Even parents whose own school mathematics outcomes were unsatisfactory often exert strong pressure to ensure that their children are taught as they were taught. Those adults who believe their mastery of mathematics to be adequate may insist on their children receiving the same type and level of mathematics instruction that they received.

The use of textbooks for the teaching of mathematics has often resulted in a "cover to cover" approach, frequently insisted upon by parents wanting to get their money's worth from the books. These books can also provide security for teachers, using them as the basis for planning instead of planning that begins with the needs of their students. "Getting through the course", textbook-based or otherwise, is frequently the driver for many primary and secondary teachers of mathematics, at the expense of a truly inclusive approach, which starts from the needs of individual students. It can also result in superficial coverage of a lot of material at the expense of deep learning of what is important.

The lack of recognition of prior mathematics learning at the transition points (for students beginning school, for students entering secondary school, and for students

entering Year 11) has resulted in many students becoming disengaged while they "wait for others to catch up".

The move to relevant, authentic tasks as a focus for teaching to engage and motivate students in meaningful contexts, particularly in the middle years, has revealed that many secondary teachers are unsure how to scaffold the learning to address the literacy and numeracy needs of students unable to access selected tasks. This can result in teachers reverting to more traditional pedagogical approaches, which results in greater student disengagement, and so on.

School leadership

The attitude and approach of school leaders are central to the creation of a climate in which many of the practices outlined above are challenged rather than perpetuated. Some principals may not know what "good practice" looks like in mathematics classrooms, placing unrealistic demands on teachers to keep their students quiet, to work in rows, and to complete lengthy sets of exercises. Pressure from parents (e.g., "I don't want my child using a calculator in primary school") or from teachers (e.g., "Students in Year 7 are beyond the need for hands-on materials.") can exacerbate this unless principals are sufficiently informed of the need, and the techniques needed, to educate parents and the school community about these issues.

Role of technology in changing practice

The role of technology in teaching, learning, doing and using mathematics has become a touchstone for a resistance to change in some quarters. The use of modern, readily available and powerful calculation tools is assumed to be either the cause, or the natural consequence, of a failure to inculcate rote learned knowledge and computational procedures.

It must be acknowledged however, that many primary teachers of mathematics are unsure of how to use a calculator as a pedagogical tool to enhance mathematical understandings and that secondary teachers, unable to remedy pre-existing conceptual weaknesses, may encourage students to use a calculator merely as a support.

Both parents and teachers need to be educated about the range of technologies now available (including calculators, advanced software, digital content and other ICT) and about the varying uses of these to enhance mathematical understanding and make computation more efficient, hence promoting confidence and subsequently numerate behaviours.

Role of language

Both the language of mathematics and the use of language in mathematics learning will impact upon students' achievements in the context of the learning area and their ability to transfer that learning to broader (numeracy) contexts. Some students will struggle with the specialist vocabulary of particular topics in mathematics because of the level of abstraction involved. Others, who apparently cope well with the demands of a mathematics task, are unable to recognise the same task when it is presented in the vocabulary and grammar of another area of the curriculum. An explicit focus on the language used in teaching and learning mathematics will remove a potential barrier to the application of classroom mathematics to everyday experiences demanding numerate behaviours.

Assessment

Results from the existing systemic testing programs (on "aspects of numeracy") contribute to judging the health of numeracy (narrowly defined) in the system. Student results on a richer and more varied range of tasks presented as part of the teaching and learning program can provide a major source of information for classroom teachers about individual students and their learning needs, and should inform teachers' pedagogical practice. Too often, those results are ignored or given diminished status compared with results from high stakes testing programs.

The high-status afforded to state-wide population tests can result in a narrow conception of classroom assessment, focusing on "what is measurable by a paper and pen test" rather than on the deep conceptual understandings of mathematics and working

mathematically aspects that the new syllabus demands. This leads to impoverished teaching and learning. The "demands of the test" can provide a convenient excuse for teachers unwilling or unable to teach for deep learning.

Systemic assessments in mathematics should avoid a focus on lower order knowledge and the recall of facts (sometimes justified on the grounds that these are easier and less expensive to mark electronically). It is impossible to test students' ability to justify, explain and interpret unless students are given the opportunity to write explanations on their papers. Students deserve the chance to demonstrate the full breadth of their learning whether in teacher-devised classroom assessment or more extensive system measures.

Equity

The relevance of the material to be learned and of the context in which it is to be applied are crucial to the development of numeracy. If the contexts are not relevant, students often will not engage and hence do not have access to the mathematics being presented. Changes in the content specifications of mathematics need to be matched by teacher preparedness to relate this to the world of the students.

Teachers of mathematics are frequently unable to personalise sufficiently the learning programs in large classes. The desire to do so, and at the same time "get through the course", creates stress and tension for many teachers who take the more familiar path of action, continuing to use outdated methods despite a recognition that they are neither engaging nor appropriate.

For indigenous students this is particularly an issue at school entry where their previous mathematical experiences through indigenous cultures are sometimes neither recognised nor valued. Adopting a "deficit" approach to teaching these students results in a lack of high expectations by teachers who may believe that many of these students will have limited success. This is often what happens, resulting in inequitable outcomes for students, as revealed through state tests.

For many students the gap between what is taught and what is learned becomes wider every year. The further they are behind what is being taught, the more difficult it is to access this. They learn to "play the game of school" and the form of assessment used can enable them to escape notice. Some students reach secondary school with mathematical understandings typical of students in the early childhood phase of learning.

Teacher preparation and professional development

In order to develop numerate citizens of the future, good teaching is essential. Since numeracy involves both the mathematics you know and the disposition to use it, teaching must focus on both of these. Numeracy is the fundamental responsibility of the mathematics learning area. There are many teachers of mathematics, both primary and secondary, who do not understand the mathematics they are teaching. They may understand the order of the steps used in procedures taught but not the deep pedagogical content needed to ensure that students learn mathematical concepts and not just the steps and routines used to produce answers. This lack of confidence on the part of teachers can be transmitted to students and result in their own lack of mathematical confidence. This aside, if teachers with a sound knowledge of mathematics focus on imparting this without using pedagogies that give students opportunities to take risks, learn from their mistakes and feel okay about that, then many students will not have the confidence to use their mathematics outside of the mathematics classroom.

Teacher training generally does not sufficiently prepare secondary teachers to know how to teach fundamental mathematics concepts such as place value and fractions. Feeling inadequate to address this issue, teachers may fall into a culture of blaming the learner and/or blaming primary teachers. Neither is productive and when combined with the pressures to "get through the course" can mean that these students fall further behind, often leaving school or reaching Year 11 without basic numeracy skills.

The implications for the teaching and learning of mathematics and developing numerate behaviours are as follows:

- teachers of mathematics must have a deep knowledge of the mathematics they are teaching;

- teachers of mathematics must understand the scope of the mathematics they are teaching and be able to make connections with the mathematics used outside of the classroom for their students;
- teachers of mathematics must use pedagogical practices that promote inquiry learning and higher-order thinking; and
- teachers of mathematics must focus on instilling a love and confidence in mathematics and its uses in contexts outside the mathematics classroom.

Queensland has an aging teacher workforce with the mean age in 2003 of 41 years and more than 10% of all teachers over 50 years of age. Some teachers are still teaching mathematics the way they were taught it 20–30 years ago. This may result from not having been specifically trained in any other approaches and methodologies for teaching mathematics (either pre- or in-service). It may also mean reliance on a very narrow approach focussing on obtaining right answers, which limits and restrains the lateral thinking demanded for real life mathematics application. Students taught in this way may never appreciate that it is the context in any particular situation that determines the level of accuracy required and that some problems have many different answers that may all be correct.

These approaches diminish student confidence and ability to take risks with their mathematics, which in turn affects their attitude and disposition towards using mathematics in real-life contexts and consequently their levels of numeracy acquisition.

Numeracy across the curriculum

The mantra that "all teachers are teachers of literacy" is now widely accepted. The same realisation that each of the Key Learning Areas offers opportunities for the development of numerate students has yet to be appreciated and acted upon in many schools. Understanding of the development and enhancement of numeracy as a shared responsibility of all teachers across all curriculum areas in all phases of schooling is essential.

An important first step is to recognise that all other learning areas place numeracy demands on learners. Many of those demands are characteristic of, and sometimes unique to, that area in their combination of mathematical content and practical context.

Examples from a range of learning areas provide an opportunity for teachers to apply or even to develop mathematics concepts in a relevant meaningful context. For example,

- What does a "blood alcohol level of 0.05%" mean?
  (Health and Physical Education)
- If 3% of the world's old growth forests are clear-felled, how much land is involved?
  (Studies of Society and Environment)
- How much bigger is a photograph after it is enlarged in the ratio 1:3? (Technology)

Teachers who grasp these opportunities to model numerate behaviour enable their students to see mathematics being used and so increase students' capacity to do the same and have confidence about applying their mathematical understandings outside the mathematics classroom.

Many teachers without specialist training in mathematics do not recognise these opportunities. Those who lack confidence in their own numeracy may actively avoid them. Such lost opportunities impoverish the curriculum in a number of ways.

When students do not have the opportunity, or lack encouragement, to transfer and apply mathematical understandings outside the mathematics classroom, their mathematical understandings are limited and lack depth. At the same time, their learning in other key learning areas is lessened through the absence of the perspective that could have been afforded by relevant mathematical knowledge or techniques. Every failure to use mathematics effectively to achieve a purpose in school decreases the likelihood that students will have the expertise, confidence and inclination to do so outside school.

The majority of teachers across the curriculum are not aware of the numeracy demands of their learning area, let alone able to seize the opportunities for teaching the mathematics in context when they are able to do so.

Within each learning area, two questions must be asked:

- How can numeracy contribute to enhanced outcomes in this learning area?
- How can this learning area enhance students' numeracy?

All teachers of all subjects must be able to help their students recognise the numeracy demands of contexts outside of mathematics itself. All teachers must seize the opportunities in day-to-day learning experiences to enhance the understanding of mathematics in context and apply their mathematical understanding to the context. Numeracy is everybody's business.

Conclusions

Although I claim this to be a comprehensive view of the issues and challenges it is unlikely to be exhaustive. Let me once a gain reiterate the acknowledgement of the fabulous practice operating in a large proportion of classrooms where mathematics is being taught and numeracy outcomes being developed. Let me congratulate these teachers wherever they are in the knowledge that they are helping the students of Australia to achieve to their highest potential in mathematics and numeracy.

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